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Assimilation of SMAP L-band Radiances Improves Near-Surface Atmospheric Humidity and Temperature in the GEOS Weather Analysis and Forecasting System

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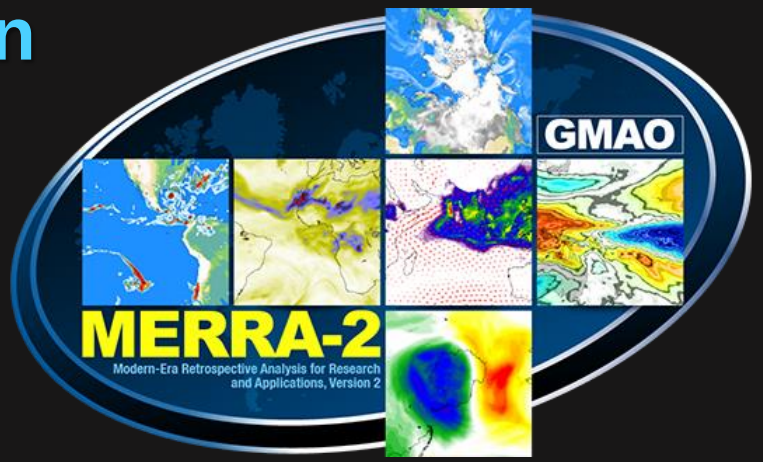
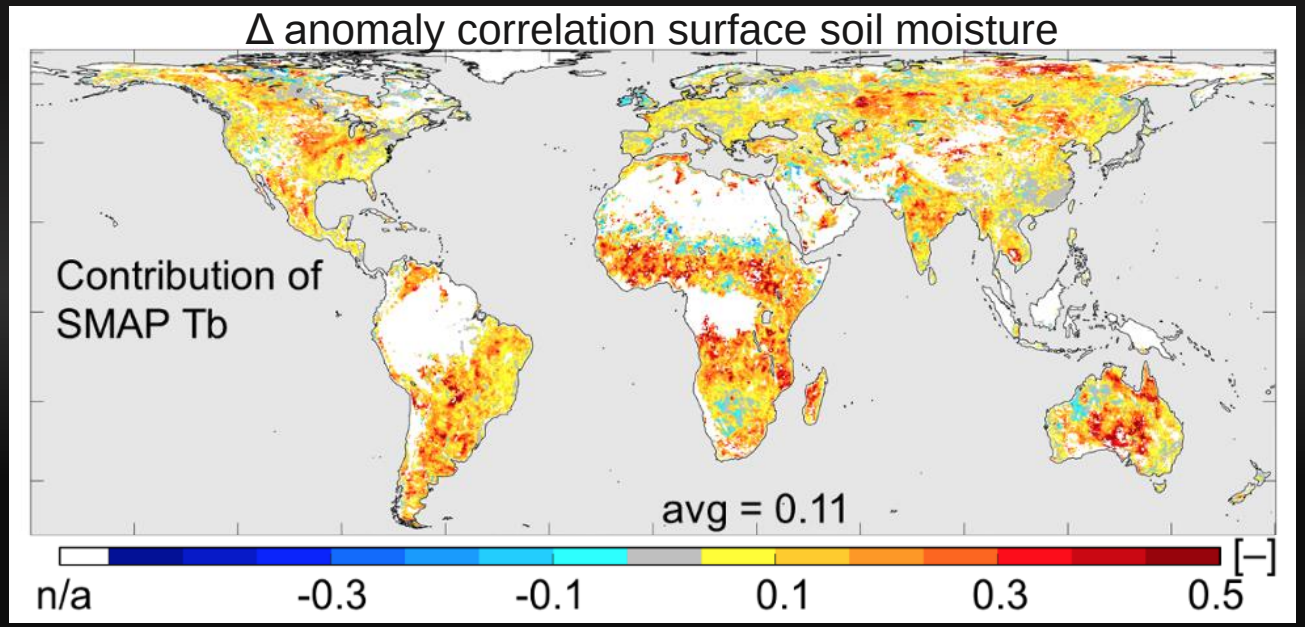
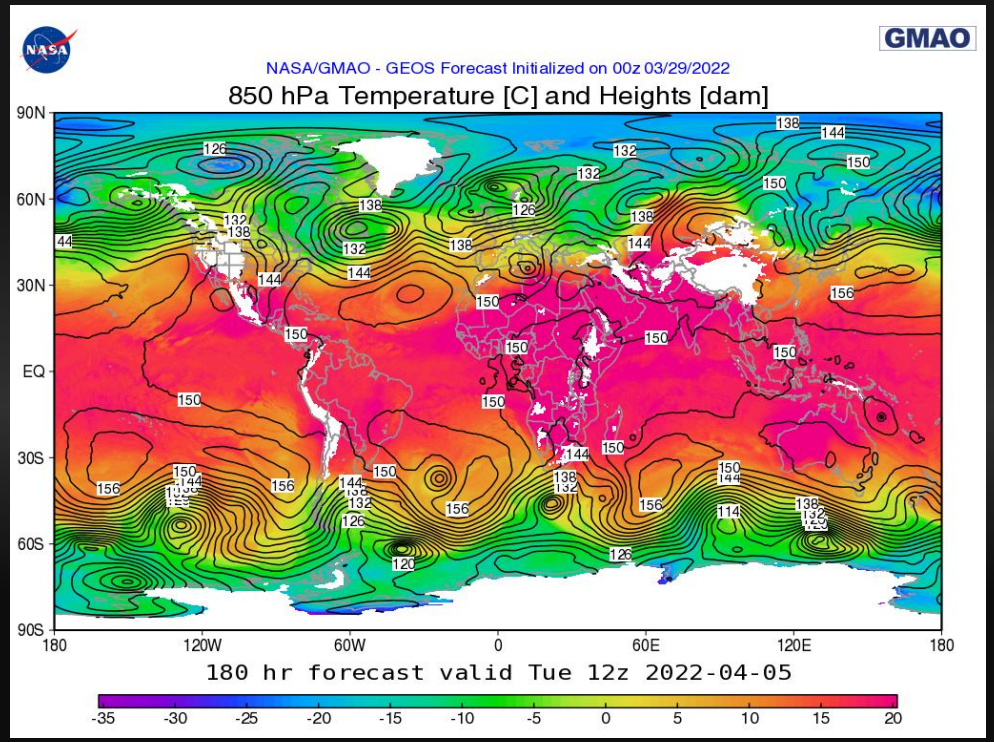
Background and Motivation

Goddard Earth Observing System (GEOS) products:

- Reanalysis
- Weather analysis and prediction (no land analysis)
- SMAP Level-4 Soil Moisture (land-only!)







Objective

Goddard Earth Observing System (GEOS) products:

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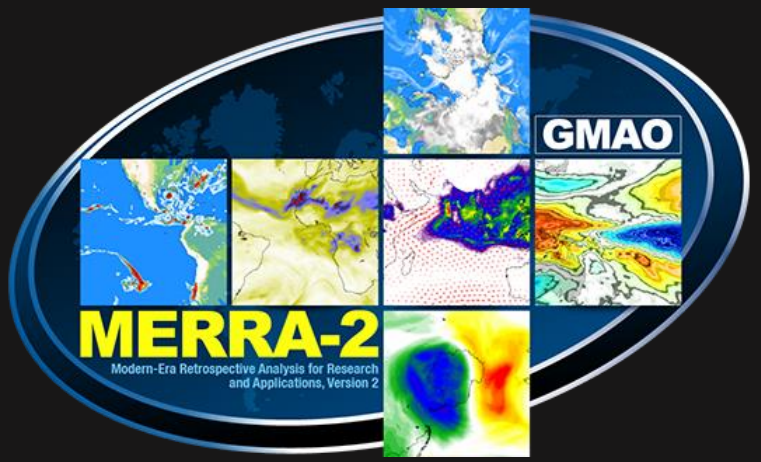
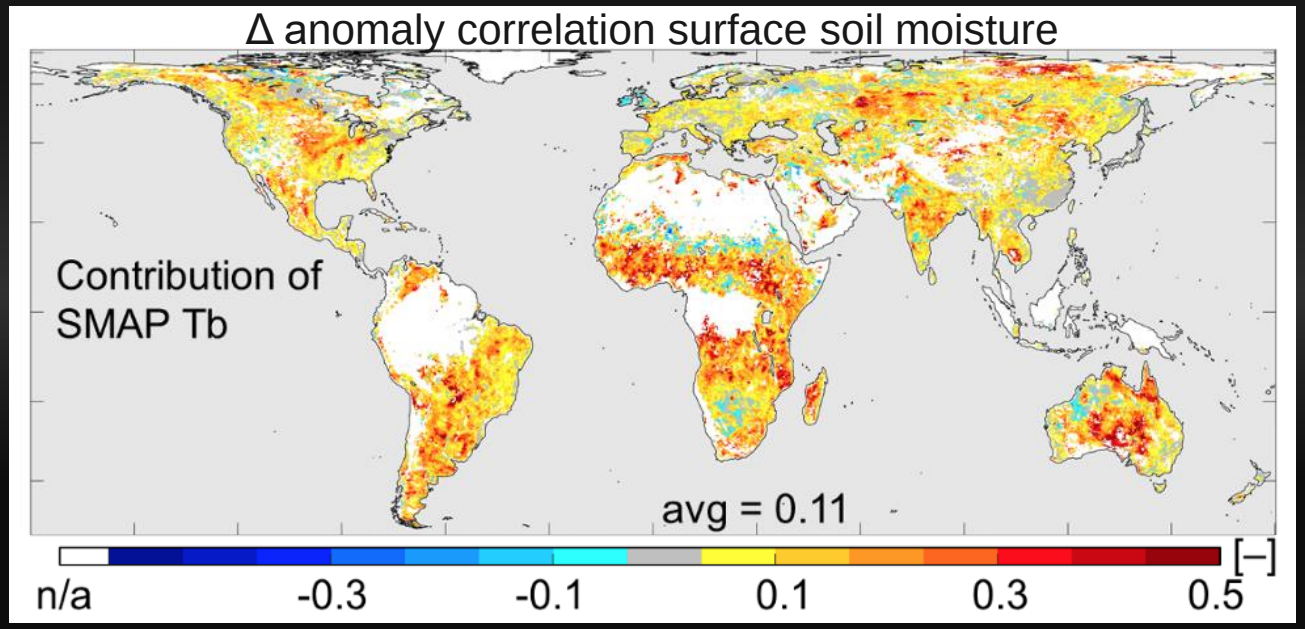
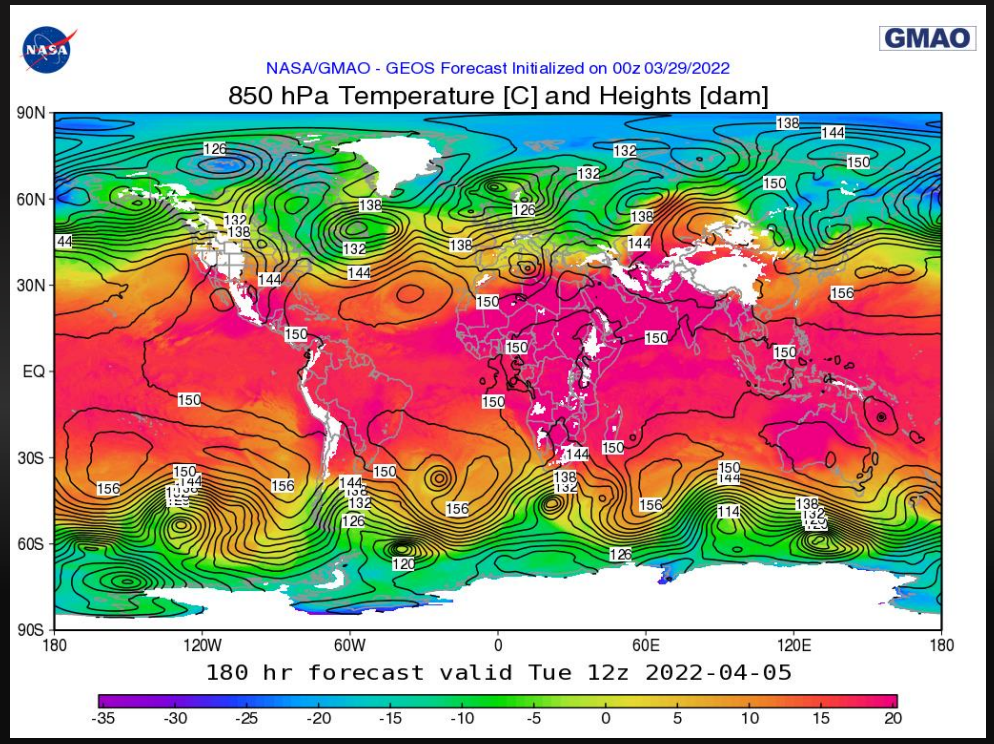
- SMAP Level-4 Soil Moisture (land-only!)







Development Overview

Draper and Reichle 2019 (MWR):

- First GEOS Land-Atmosphere DAS (LADAS)
- ~GEOS 5.12.4 (MERRA-2) model and ADAS (3D-Var)
- SMOS and ASCAT soil moisture retrieval assimilation (1D-EnKF)
- Experiment: MJJA 2013 at 0.5 deg

Reichle et al. 2021 (IEEE):

- GEOS 5.26.4 in 3D-Var configuration
- SMAP radiance (Tb) assimilation as in SMAP L4_SM (3D-EnKF; Reichle et al. 2019)
- Experiment: JJA 2017 at 0.5 deg

Recently:

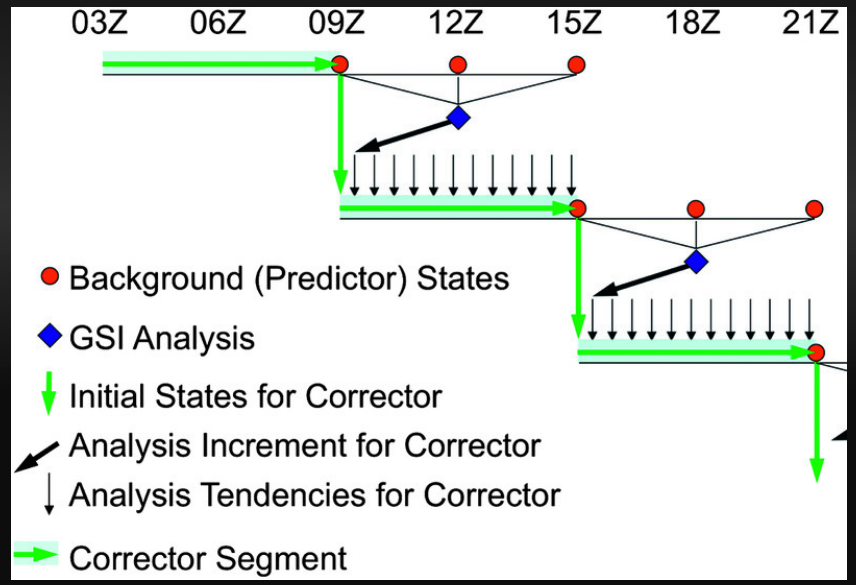
- GEOS 5.29.x in 4D-Hybrid-EnVar configuration
- SMAP radiance (Tb) assimilation as in SMAP L4_SM (3D-EnKF)
- Experiment: JJA 2017 at 0.5 deg (incl. forecasts)

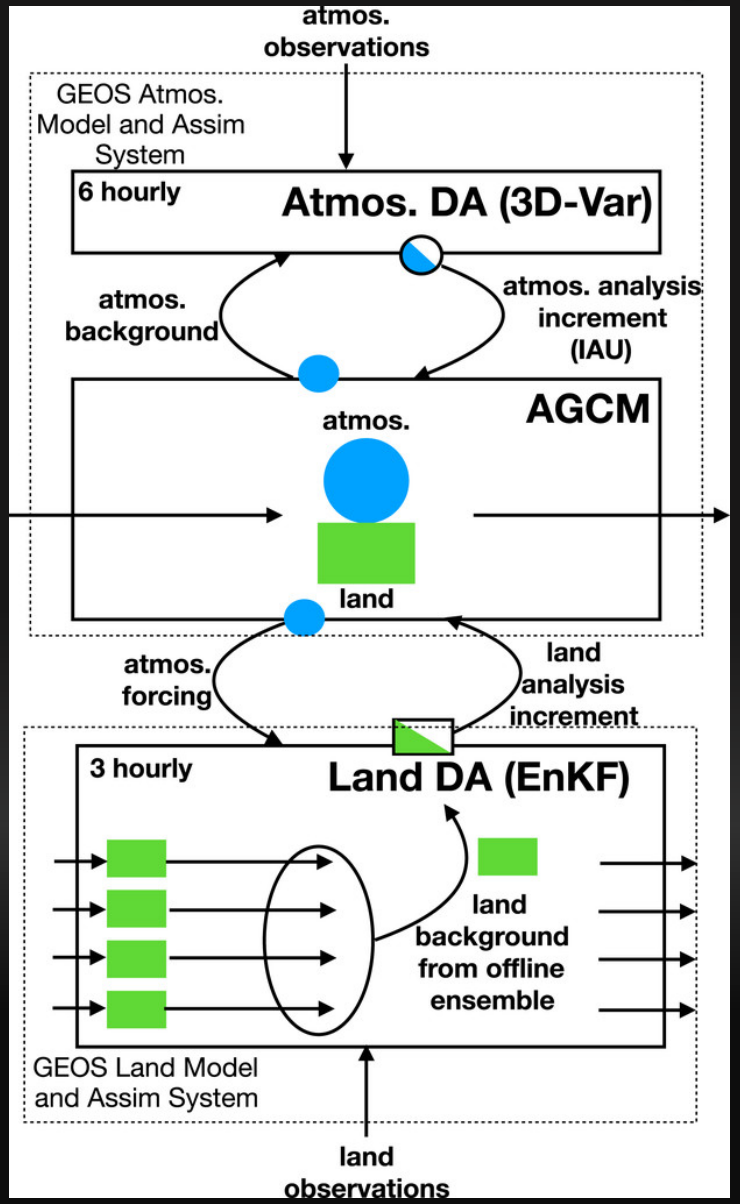
Draper & Reichle (2019) doi:10.1175/MWR-D-18-0393.1
Reichle et al. (2019) doi:10.1029/2019MS001729
Reichle et al. (2021) doi:10.1109/JSTARS.2021.3118595

Land-Atmosphere Data Assimilation System (LADAS)

ADAS (3D-Var):

1. Predictor: 6-hour AGCM forecast from previous cycle.
2. Atmospheric analysis (GSI): Compute atmospheric analysis increments.
3. Corrector: Re-integrate 6-hour segment with atmos. corrections.





LADAS:

1. As in ADAS.
2. Add land analysis (EnKF) to produce soil moisture increments.
3. Add soil moisture corrections.

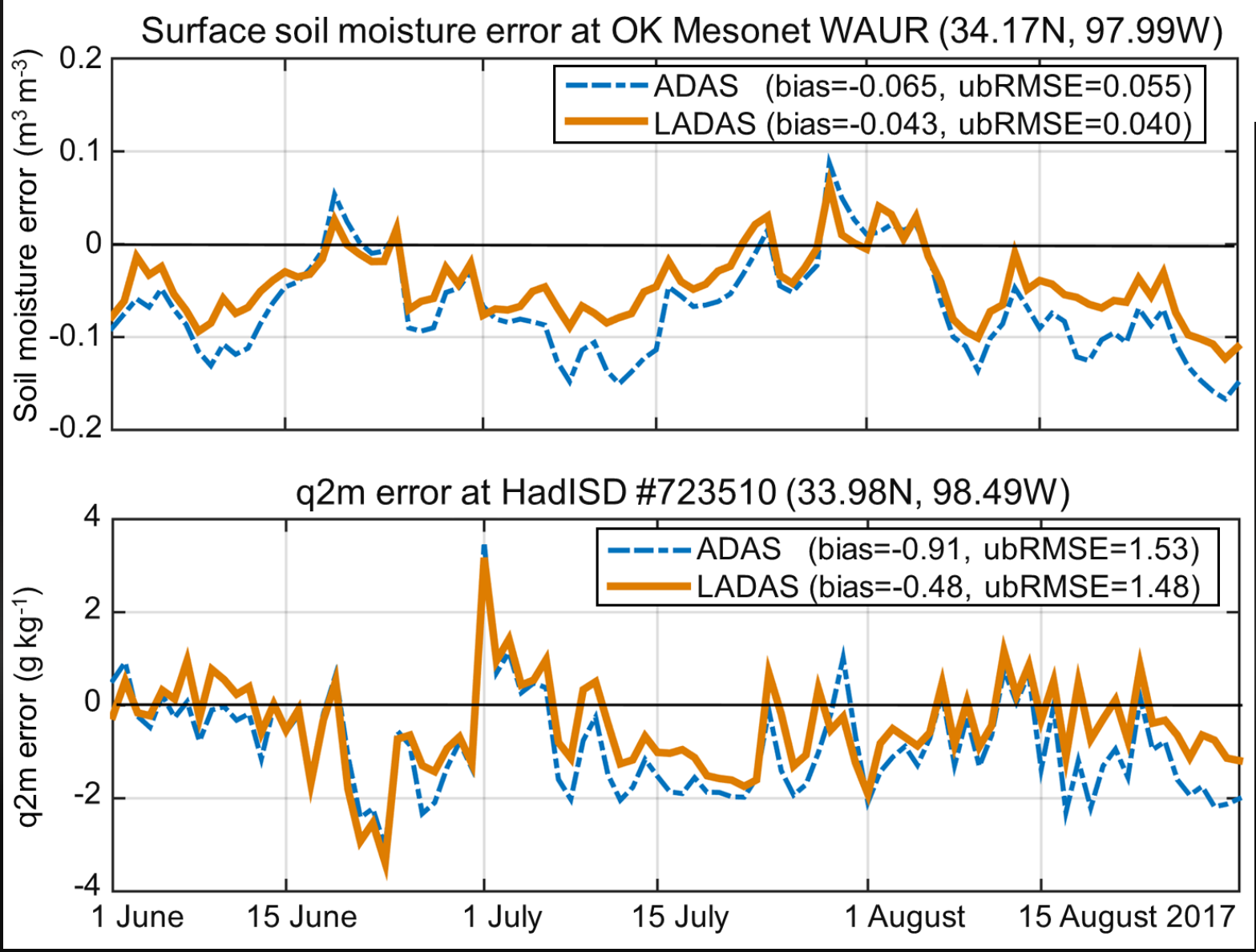
Atmosphere and land analysis are weakly coupled through model physics.

Same general approach with 4D-Hybrid-EnVar (but need two LDAS instances).

Notation for Results Slides

“ADAS”	≡ CTRL	(no SMAP assim.)
“LADAS”	≡ Experiment	(with SMAP assim.)

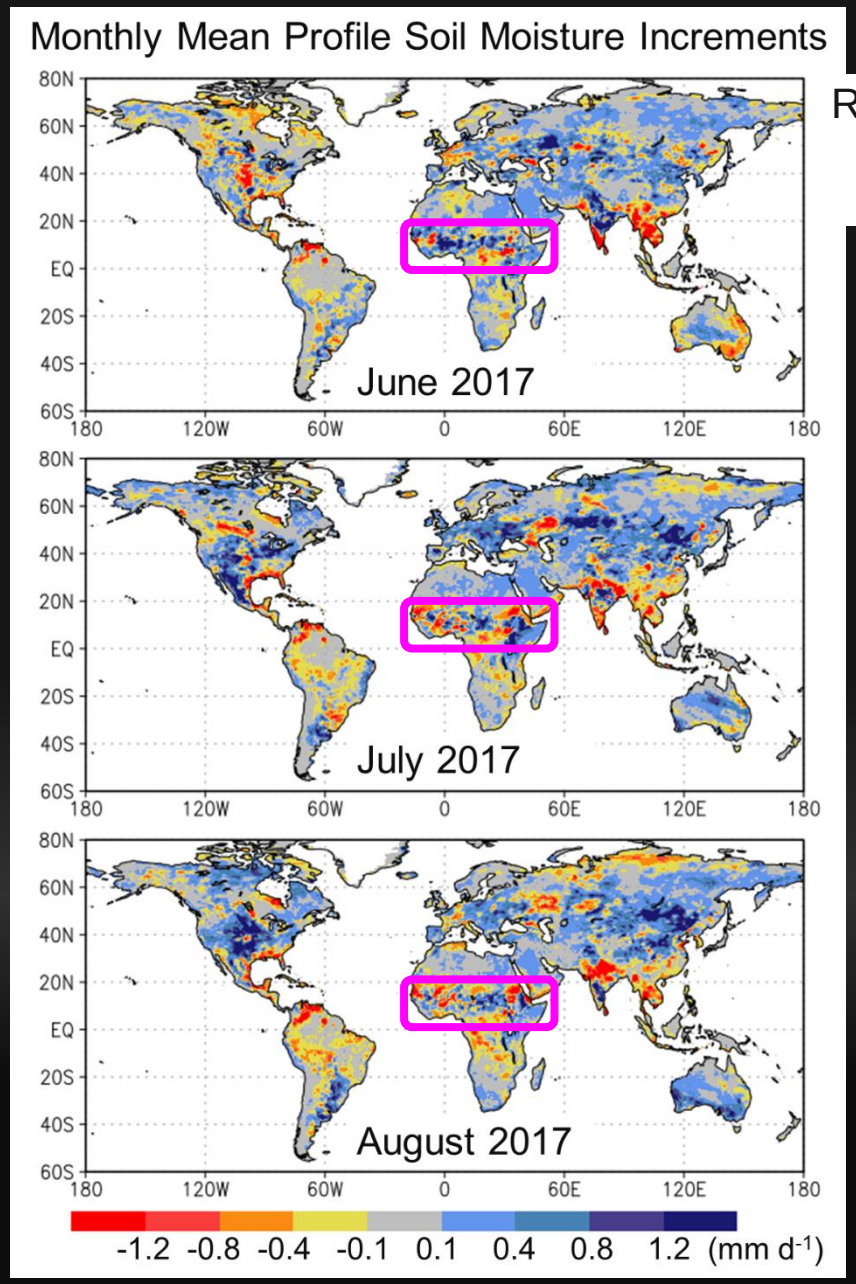
Impact on Screen-Level Specific Humidity (q2m)



Reichle et al. 2021

Improved soil moisture translates into improved q2m.

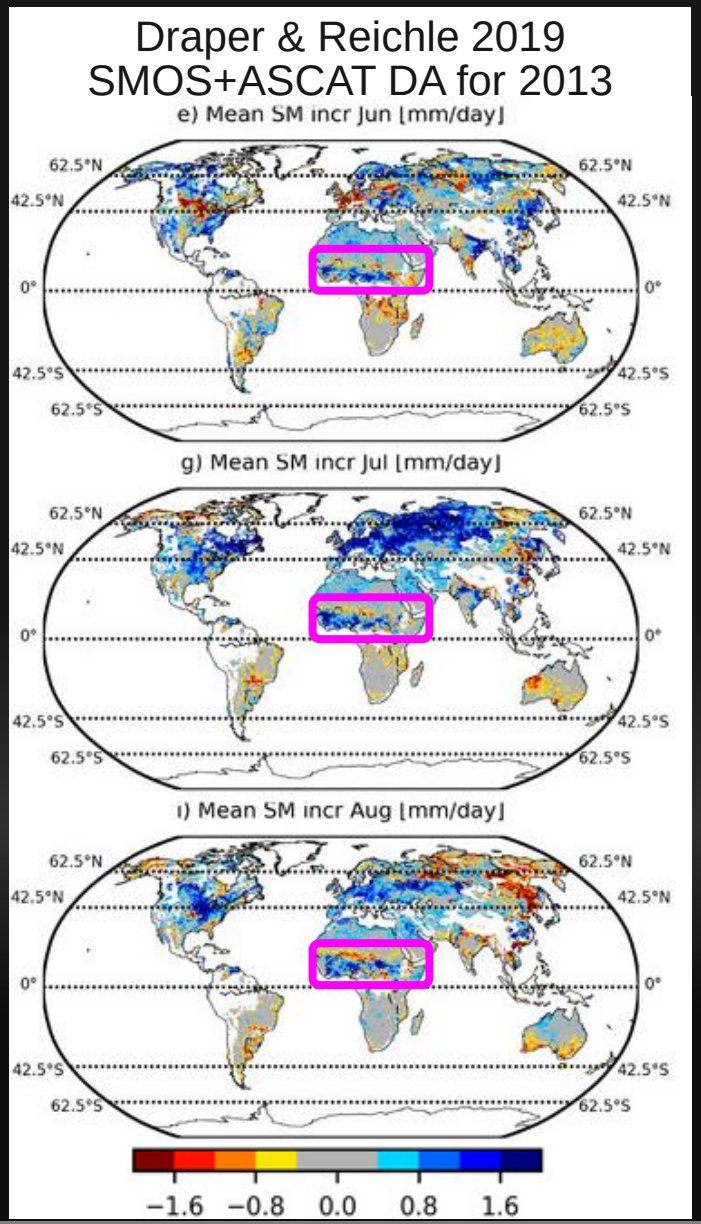
Soil Moisture Analysis Increments



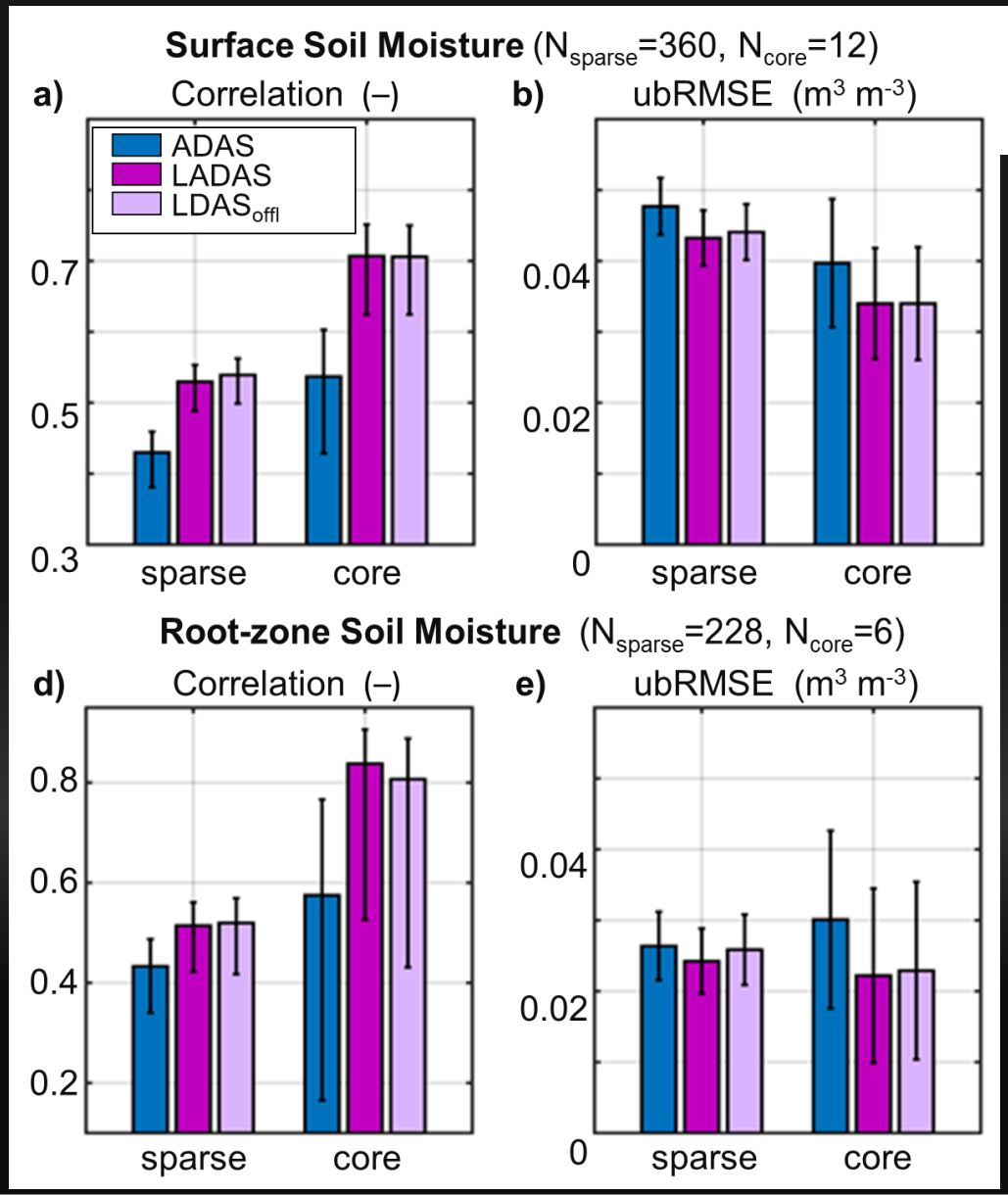
Reichle et al. 2021

Consistent with L4_SM diagnostics.

More spatio-temporal variability than seen in (Draper & Reichle 2019).



In Situ Soil Moisture Validation



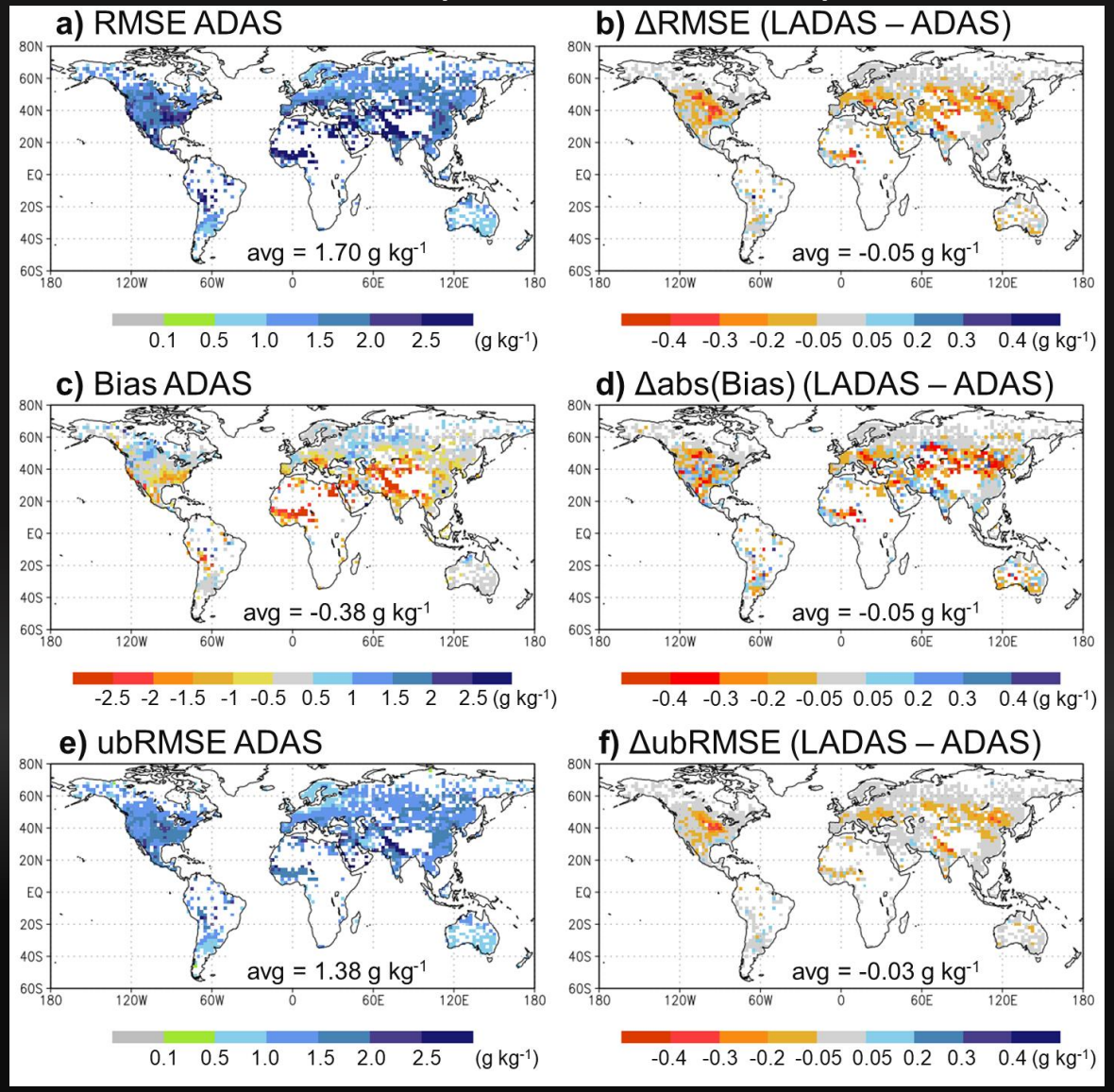
Reichle et al. 2021

Soil moisture skill improvements over ADAS (consistent with L4_SM improvements over land model-only simulation).

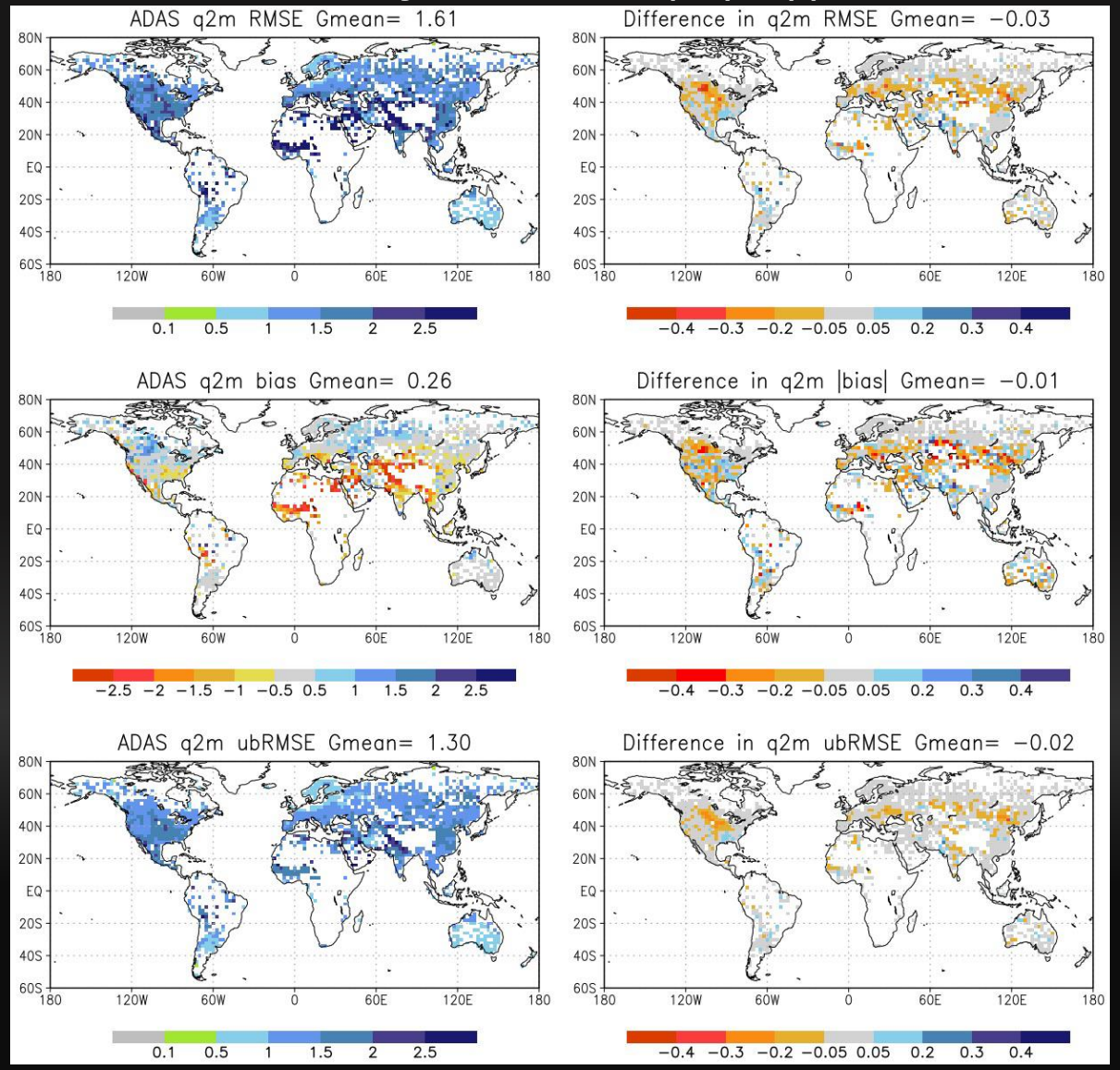
Improvements statistically significant for surface soil moisture correlation.

Screen-Level Humidity (q2m) vs. HadISD

3D-Var (Reichle et al. 2021)

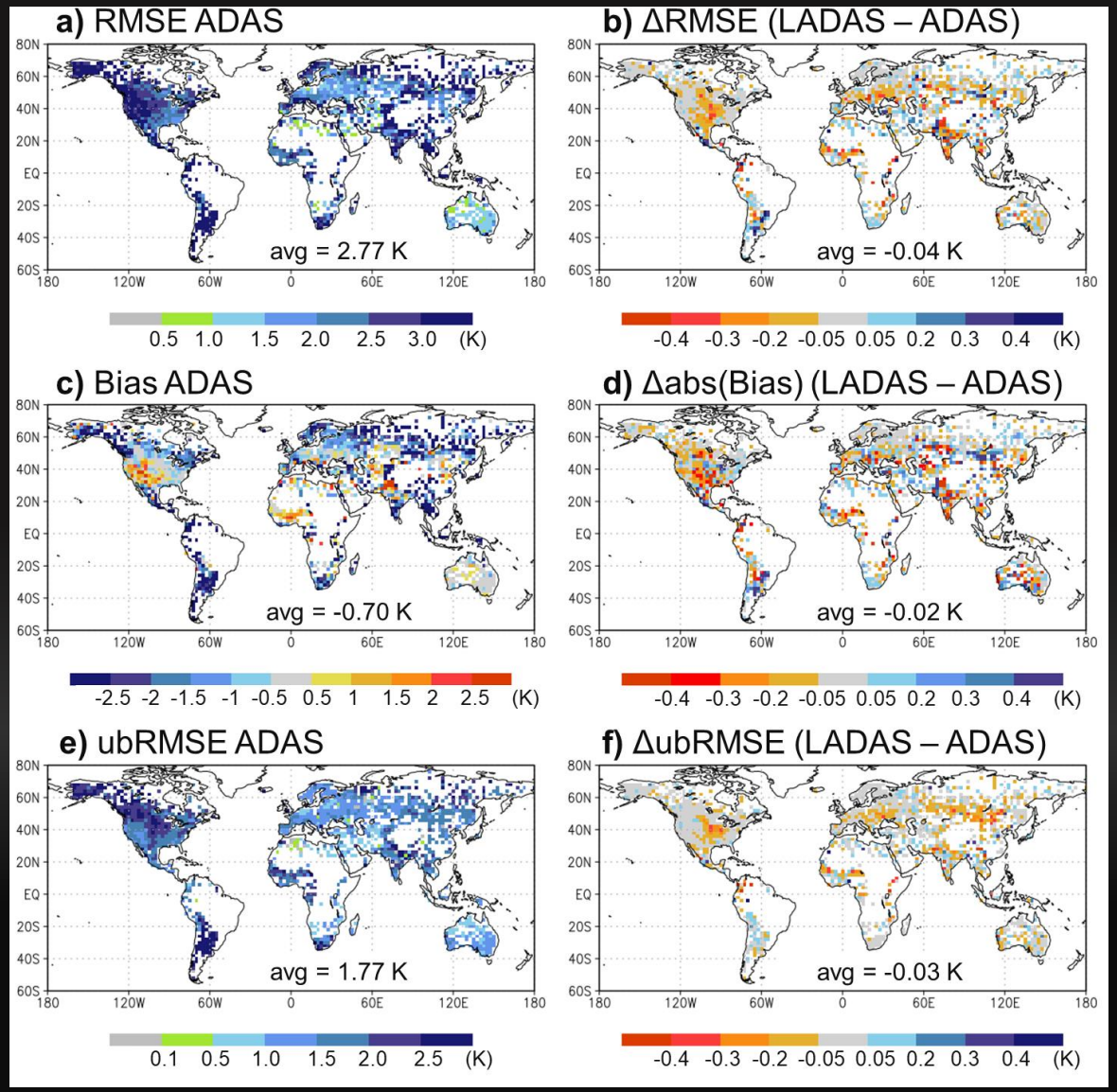


4D-Hybrid-EnVar (in prep)

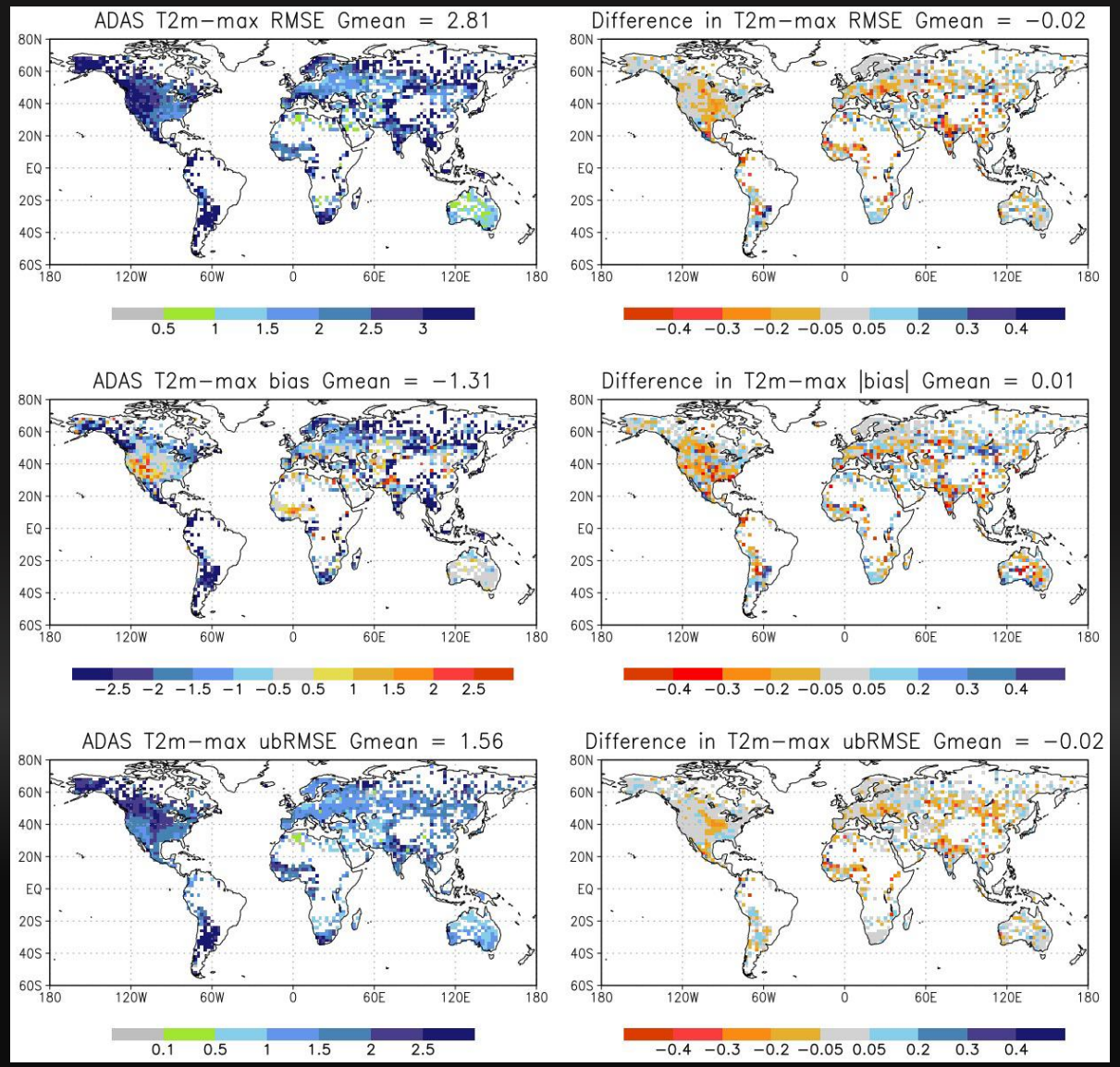


Screen-Level Daily Max Air Temperature ($T2m_{max}$) vs. GHCN

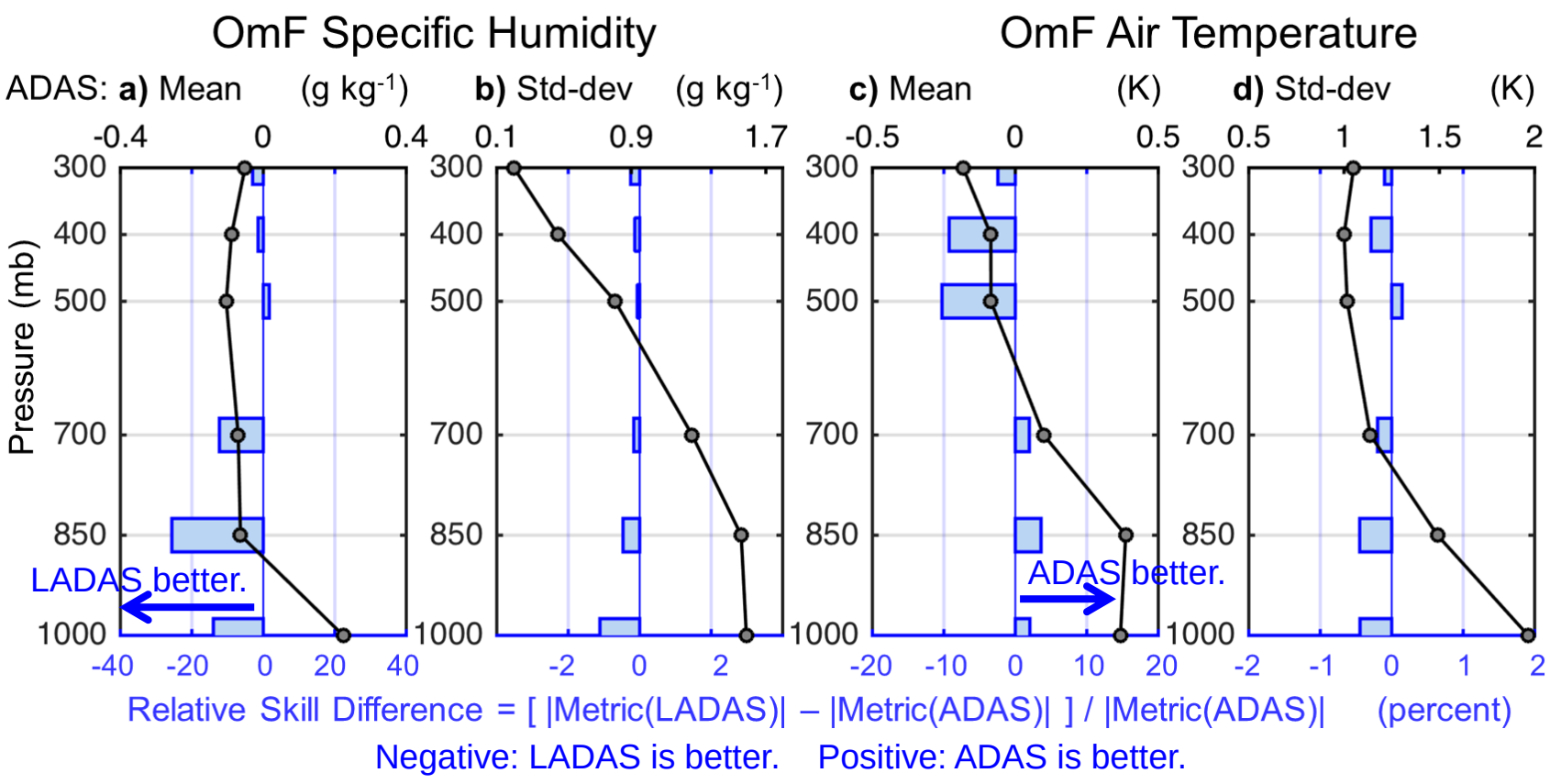
3D-Var (Reichle et al. 2021)



4D-Hybrid-EnVar (in prep)



Atmospheric Profiles

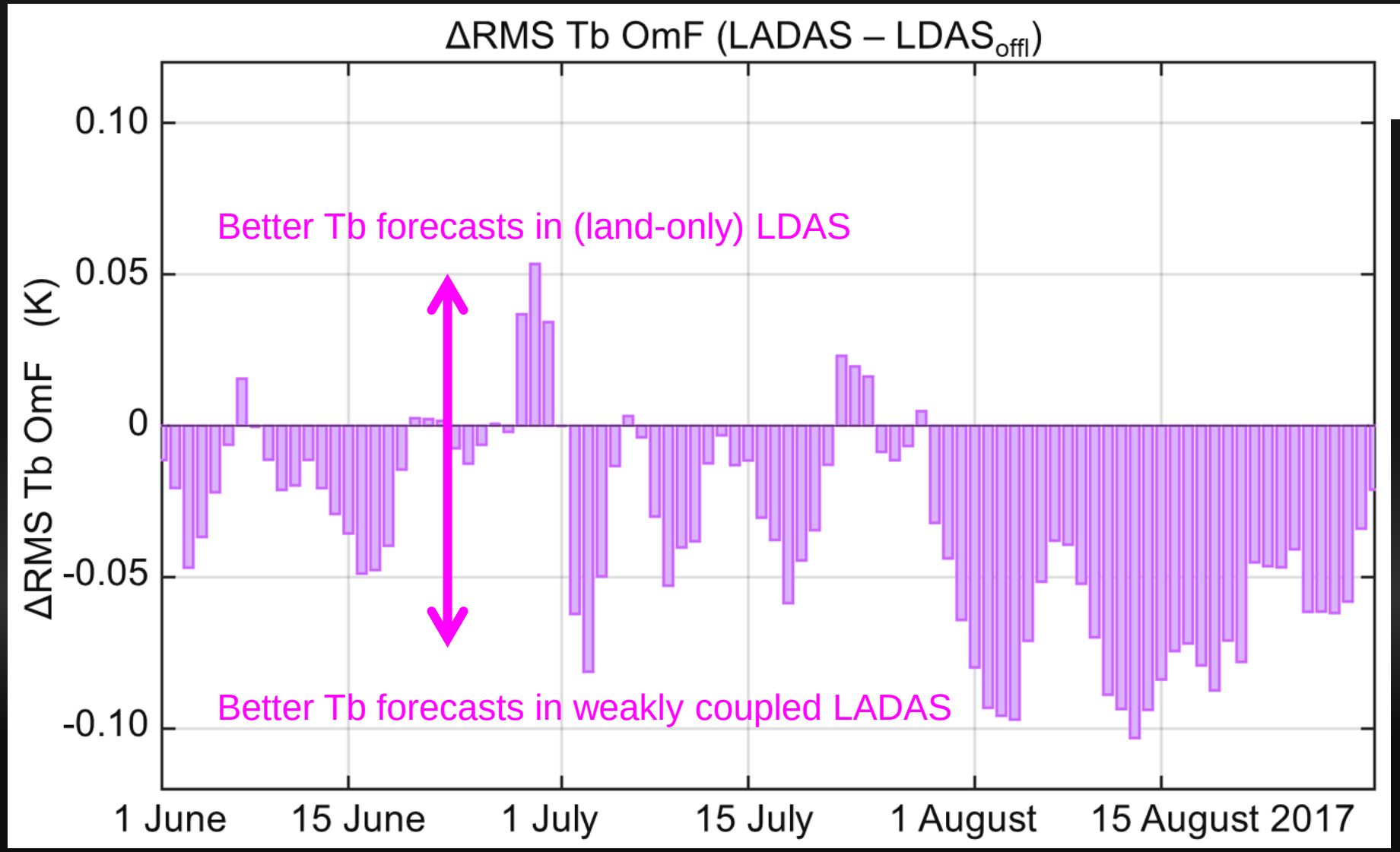


Reichle et al. 2021

O-minus-F stats for radiosondes over continental land.

Improvements in specific humidity extend into the lower troposphere (below ~700 mb).

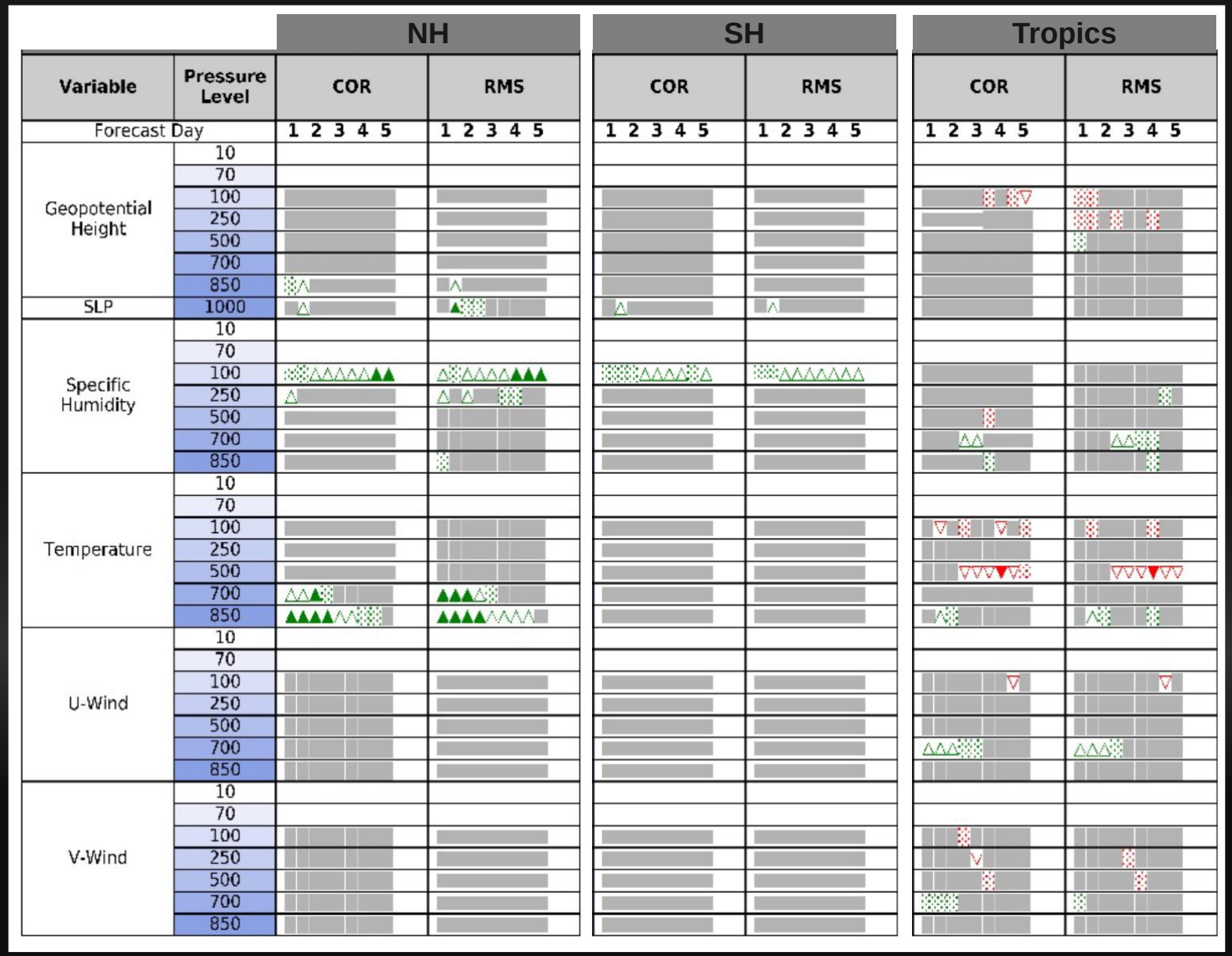
Weakly-coupled LADAS vs. land-only LDAS



Reichle et al. 2021

Weakly coupled system improves land surface forcing!

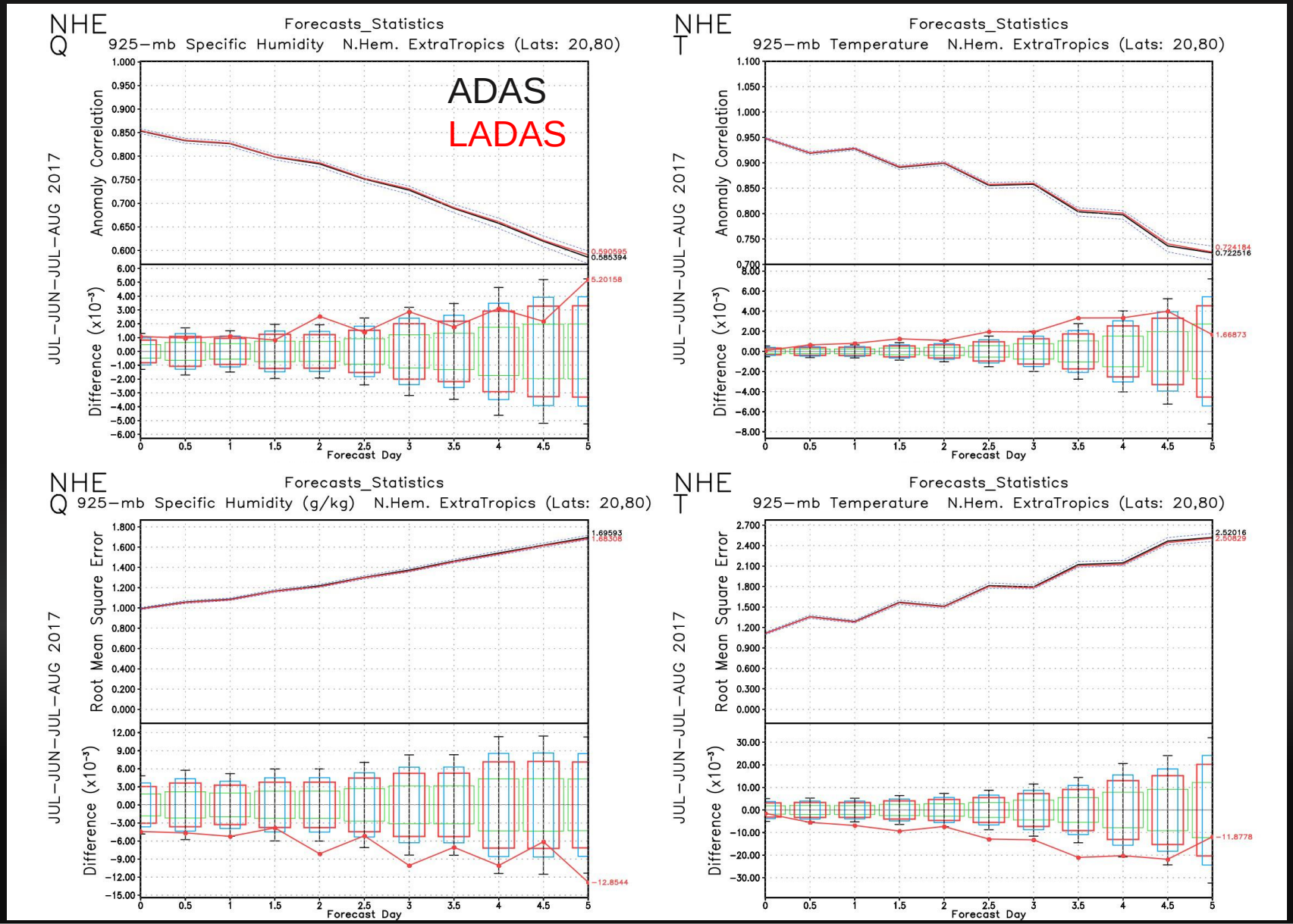
4D-Hybrid-EnVar LADAS and CTRL vs ECMWF (Jun 21-Aug 31, 2017)



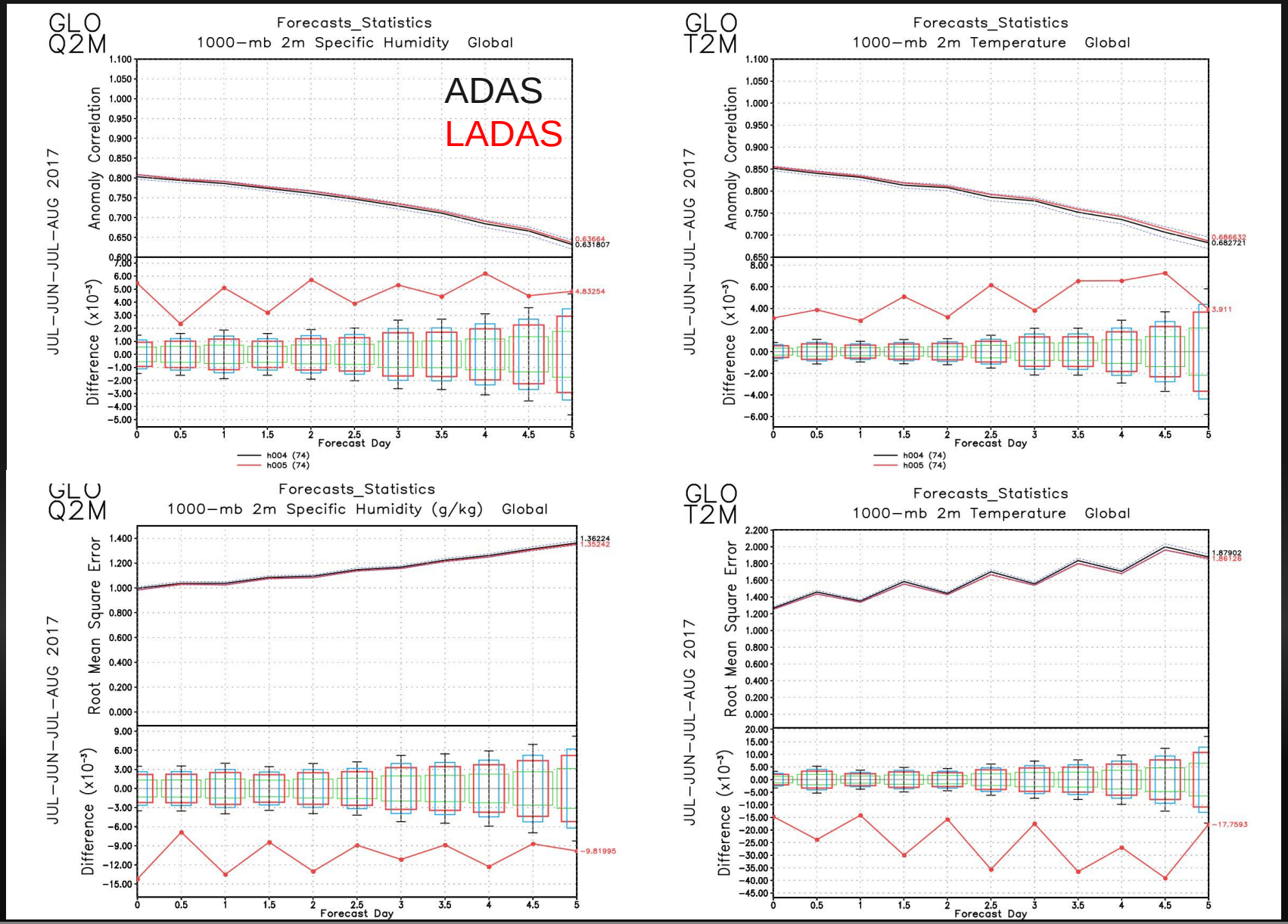
Standard GEOS score card does not get close to the surface…

- ▲ far better, significant (99.99% confidence)
- △ better, significant (99% confidence)
- slightly better, significant (95% confidence)
- no significant difference
- slightly worse, significant (95% confidence)
- ▽ worse, significant (99% confidence)
- ▼ far worse, significant (99.99% confidence)

4D-Hybrid-EnVar LADAS and CTRL vs ECMWF (925 mb, NH)

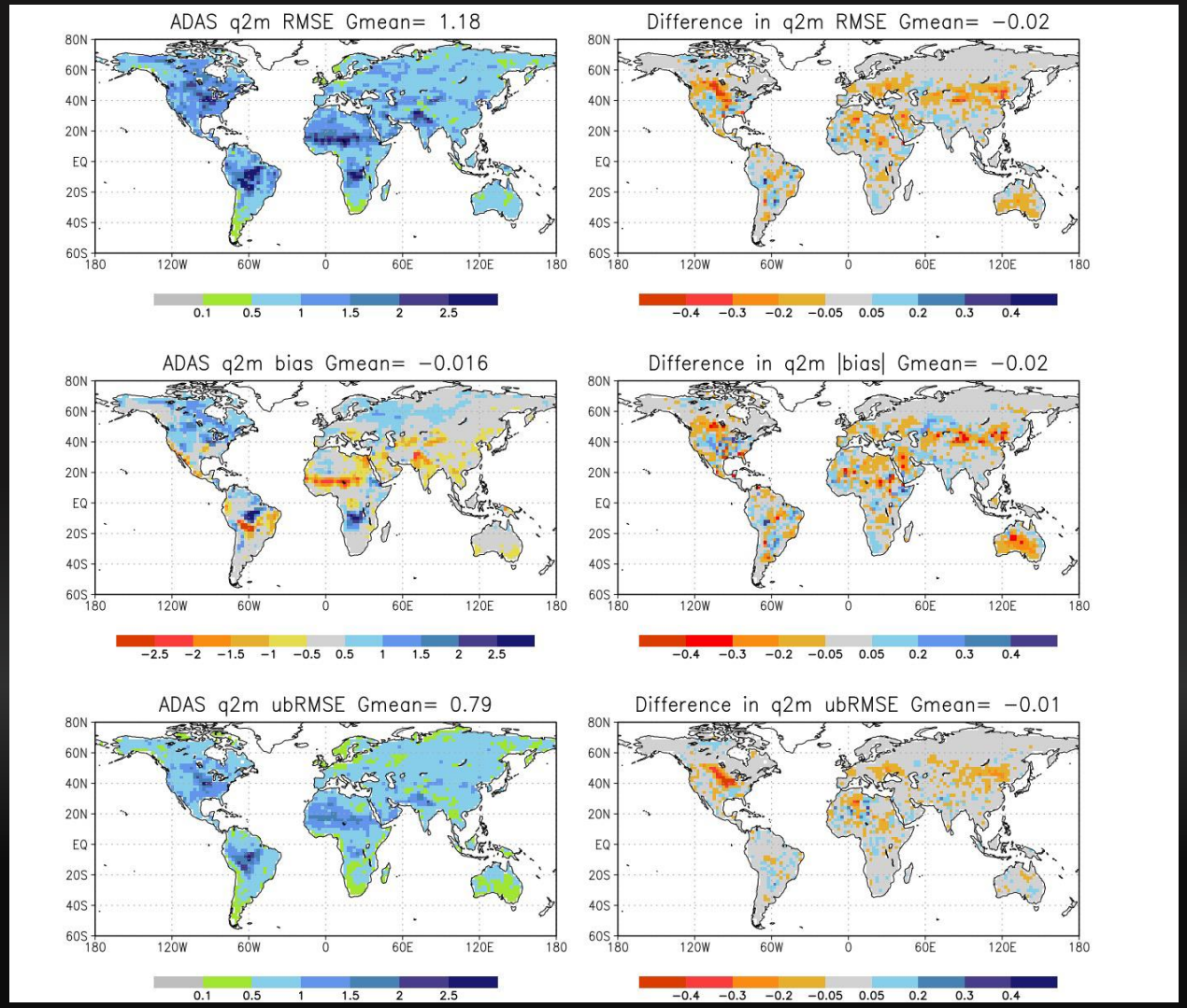


4D-Hybrid-EnVar LADAS and CTRL vs ECMWF (Screen-Level, Global)

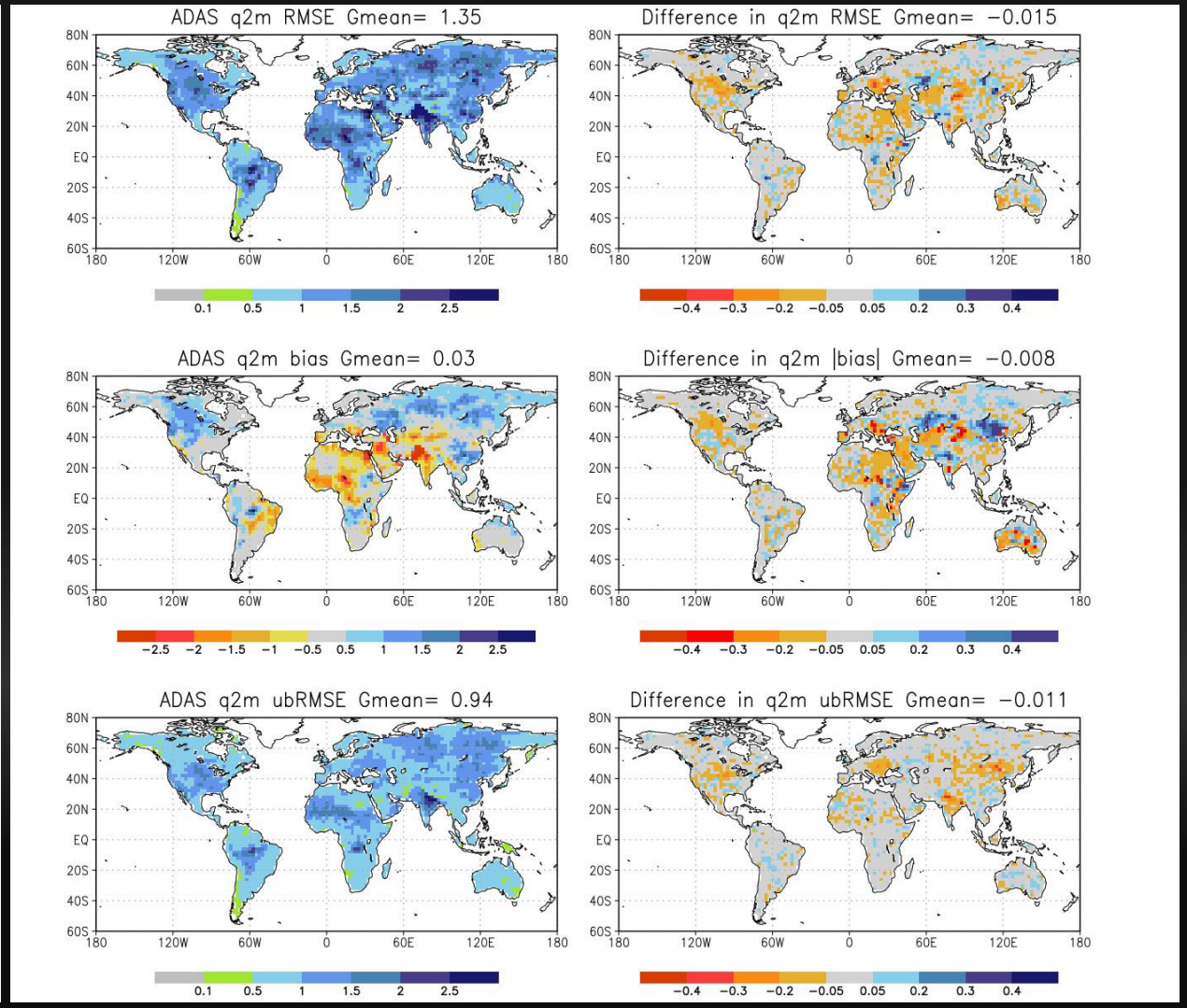


Screen-Level Specific Humidity (q2m) vs. ECMWF

Analysis (0z)



2.5-day Forecast



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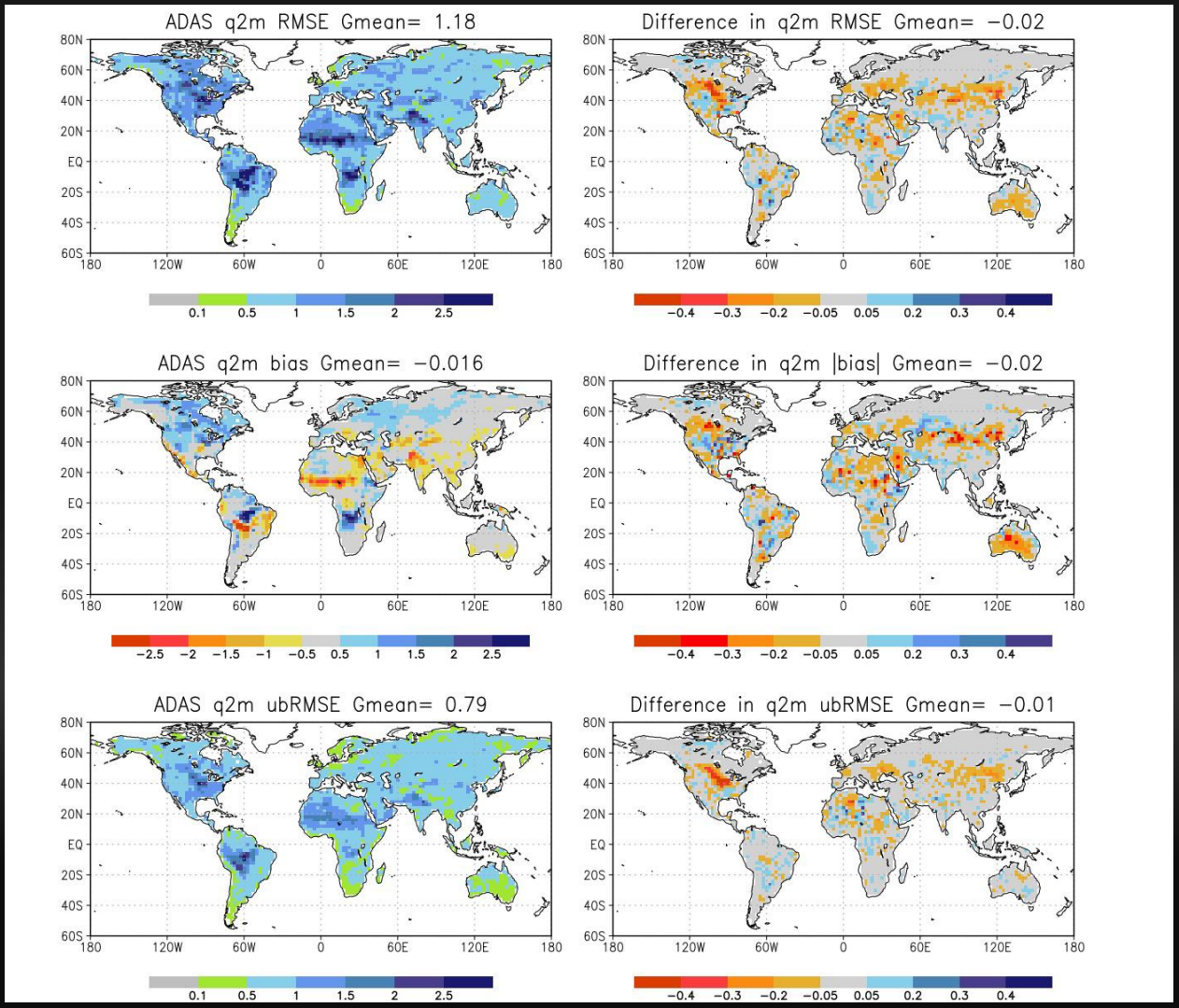
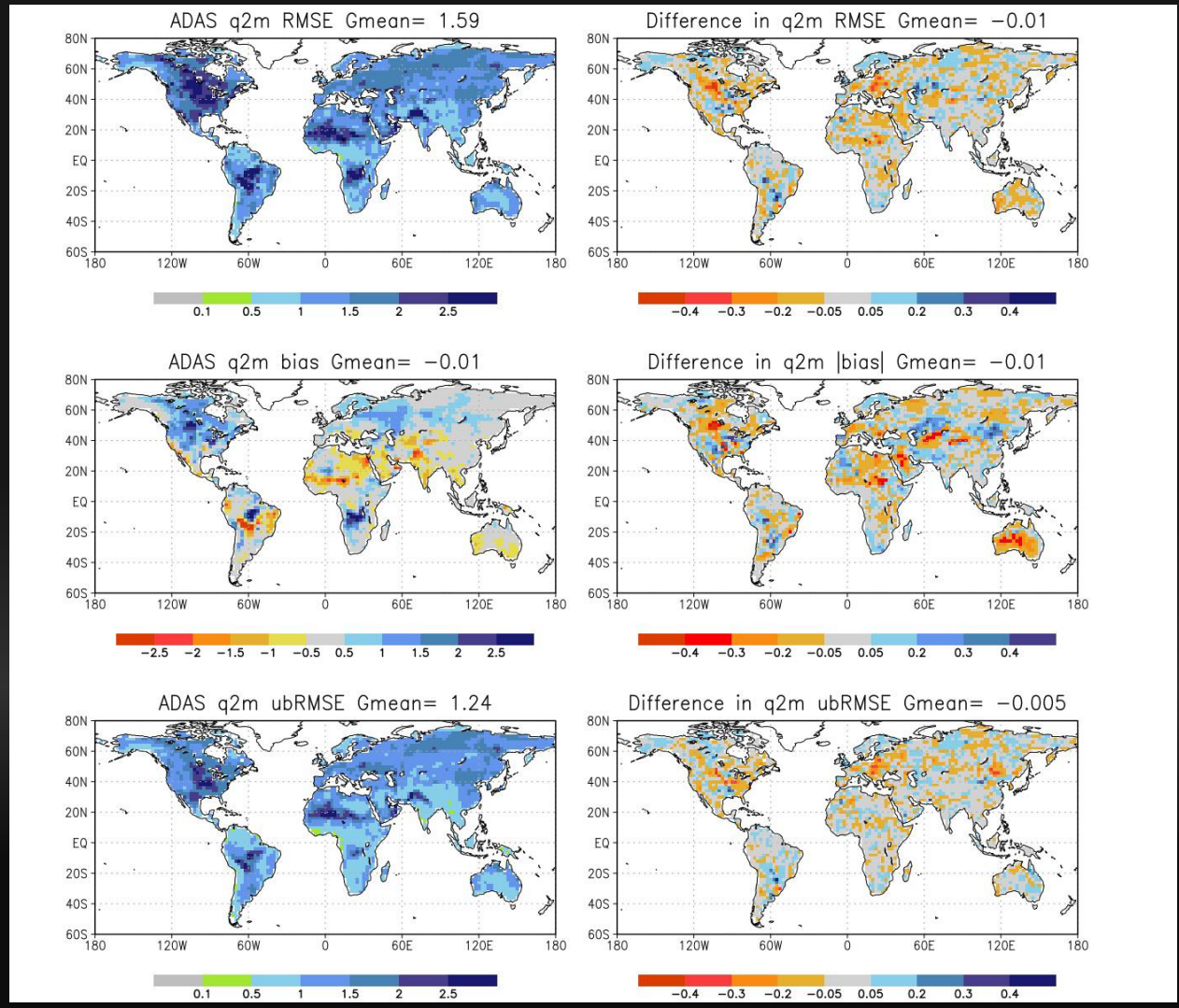
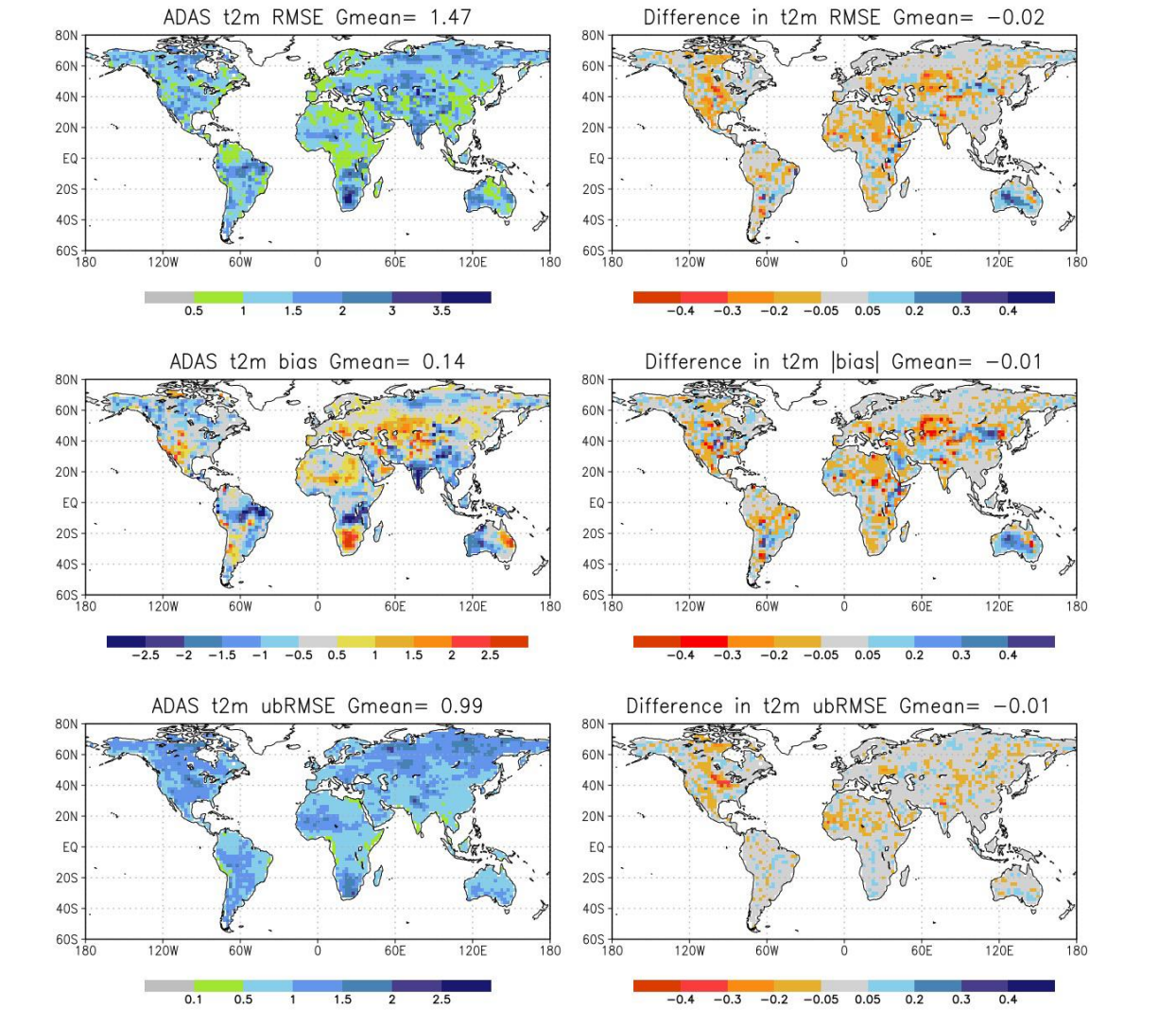


5-day Forecast



Screen-Level Air Temperature (T2m) vs. ECMWF

Analysis (0z)



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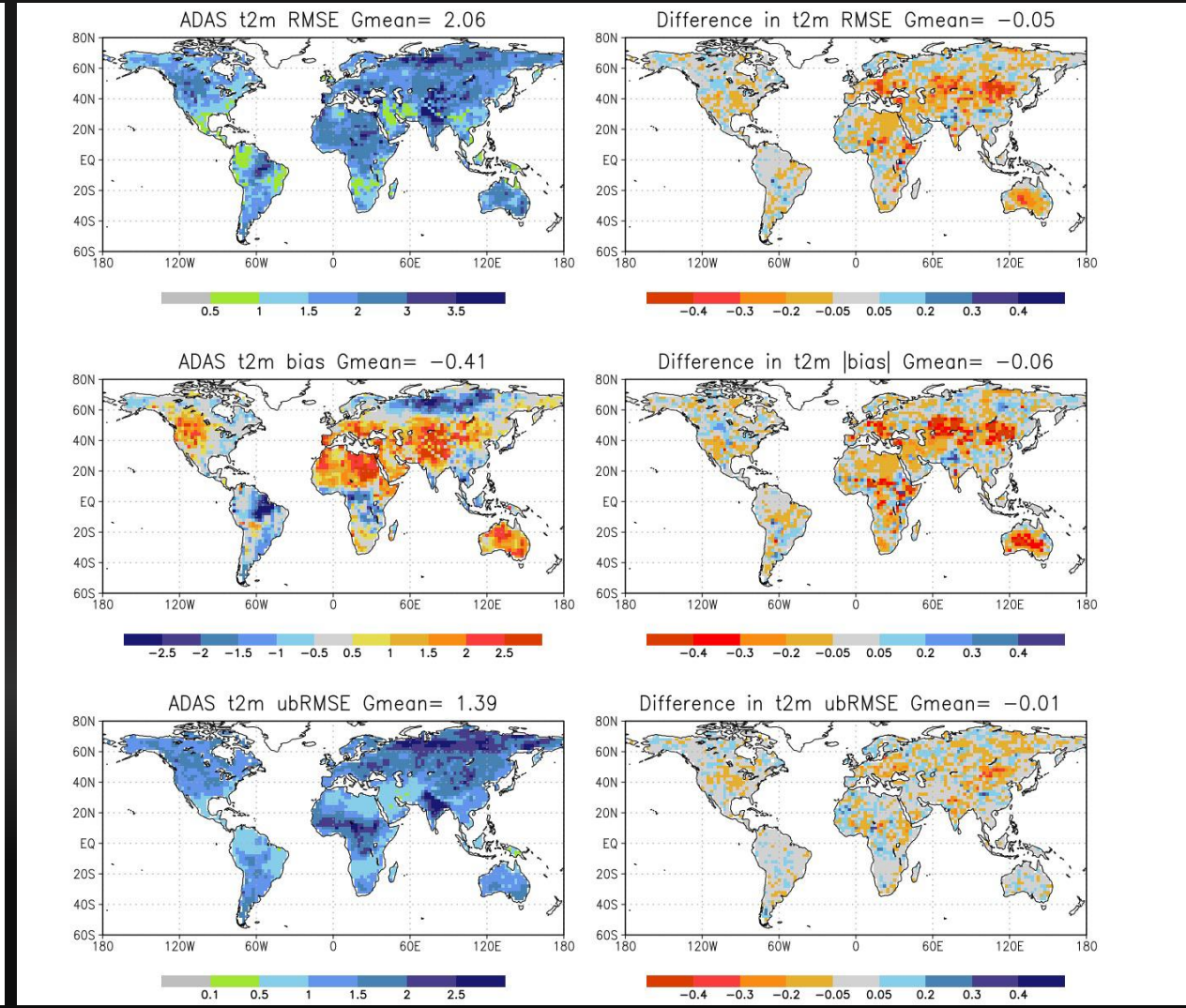

Screen-Level Air Temperature (T2m) vs. ECMWF

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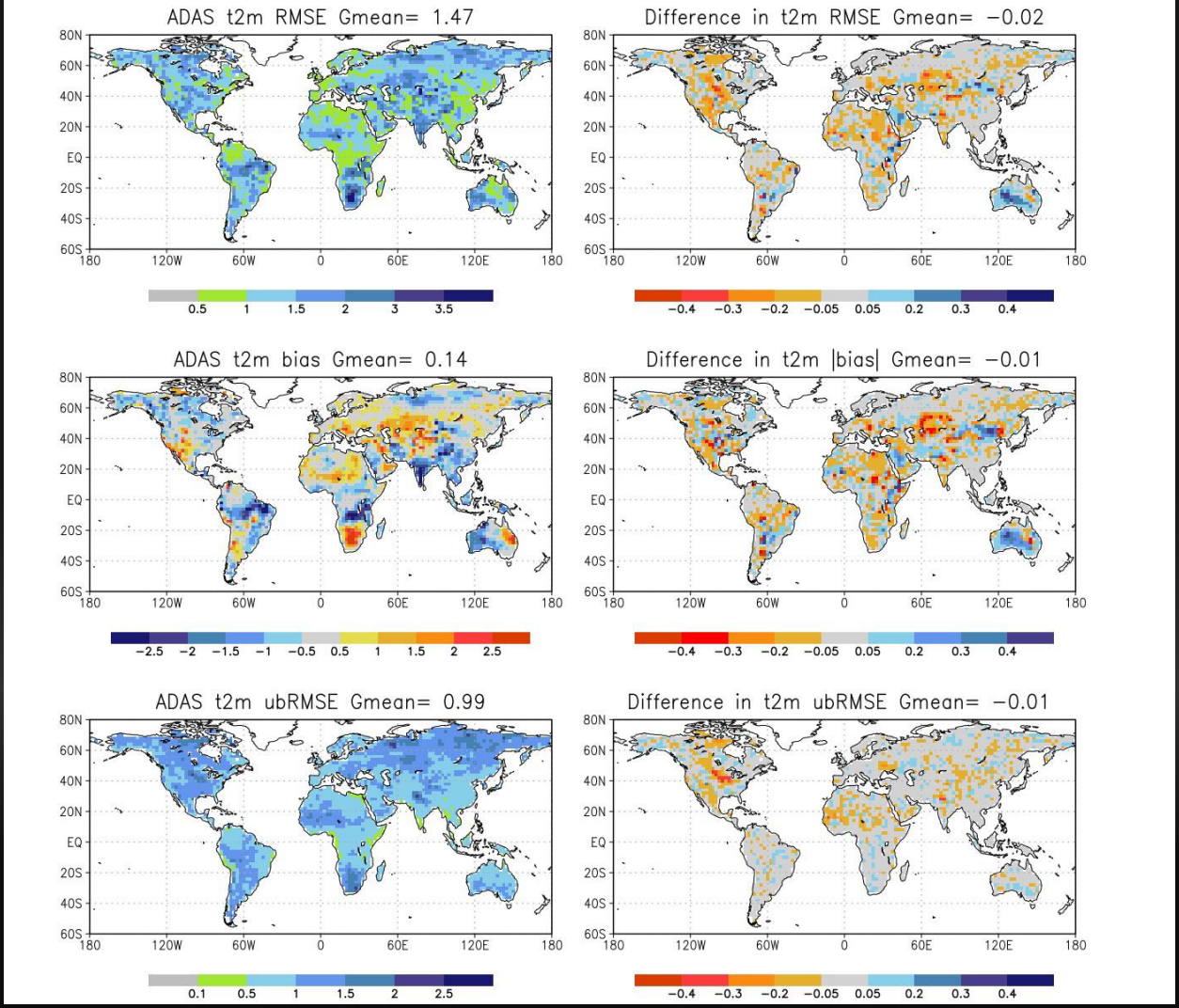

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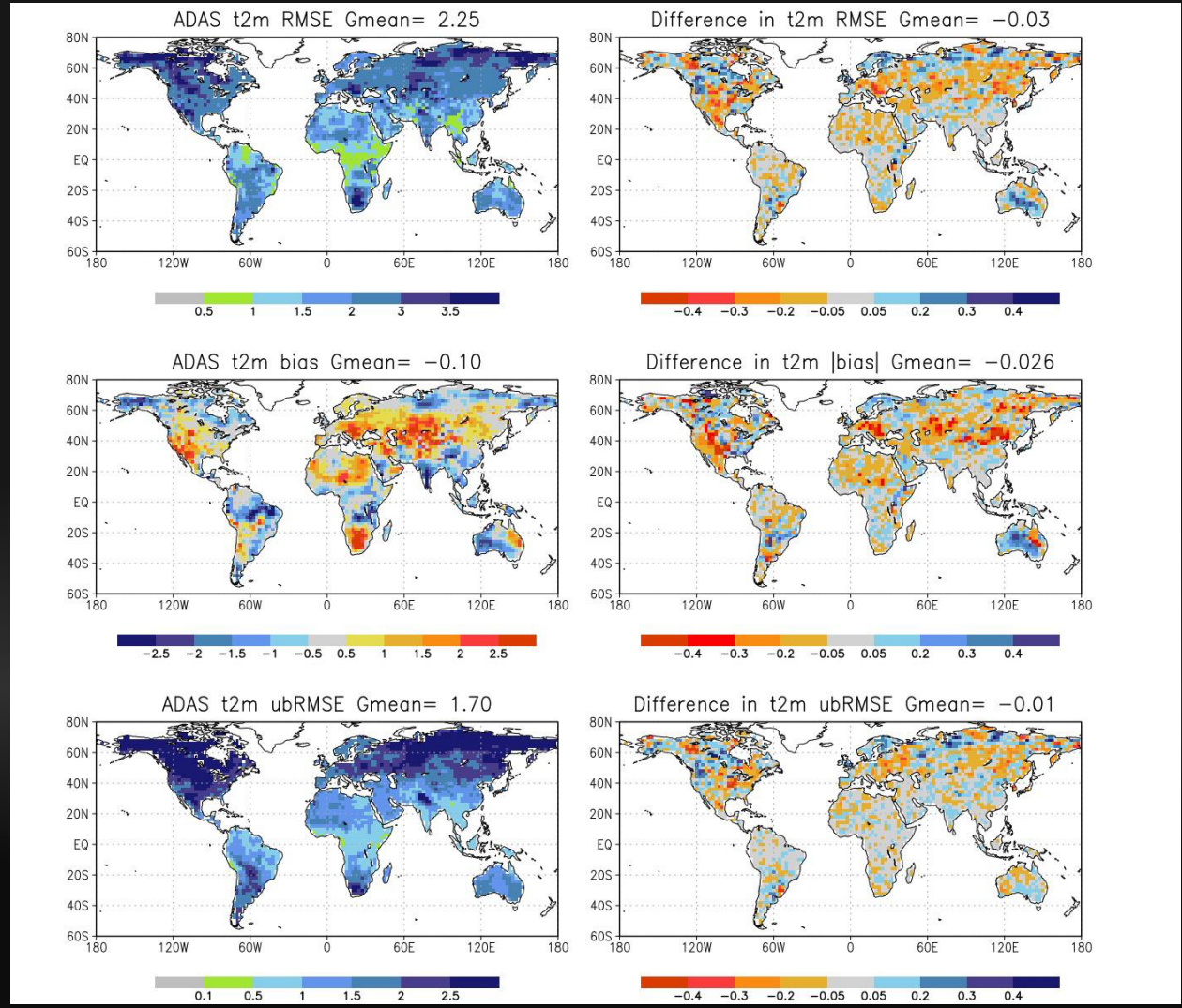

Current Work and Next Steps

- Conducting 4D-Hybrid-EnVar experiments at 0.25 deg resolution for SMAP Tropical Cyclone project.
- Adding screen-level verification into standard package for die-off curves and score card.
- Connecting ADAS and LDAS ensembles.

- Investigate surface turbulent flux estimates.

- Include and verify in formal “X” experiment for system development.
- Add plumbing for near-real time SMAP Tb.
- Test in “parallel” operations.